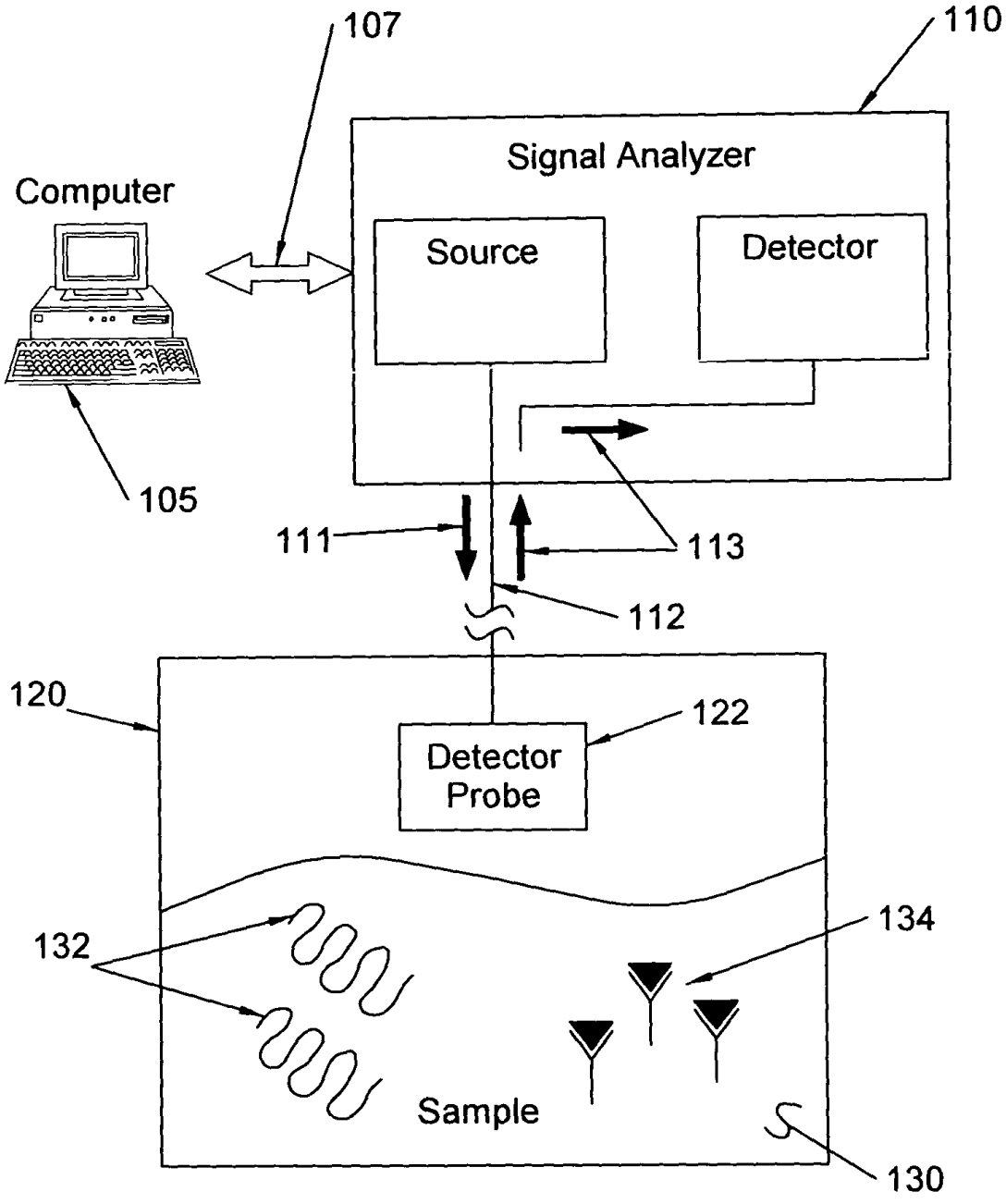
107
110
Signal Analyzer
Computer
Source
Detector
105
111
113
112
120
122
Detector
Probe
132
134
Sample
130

FIG. 1

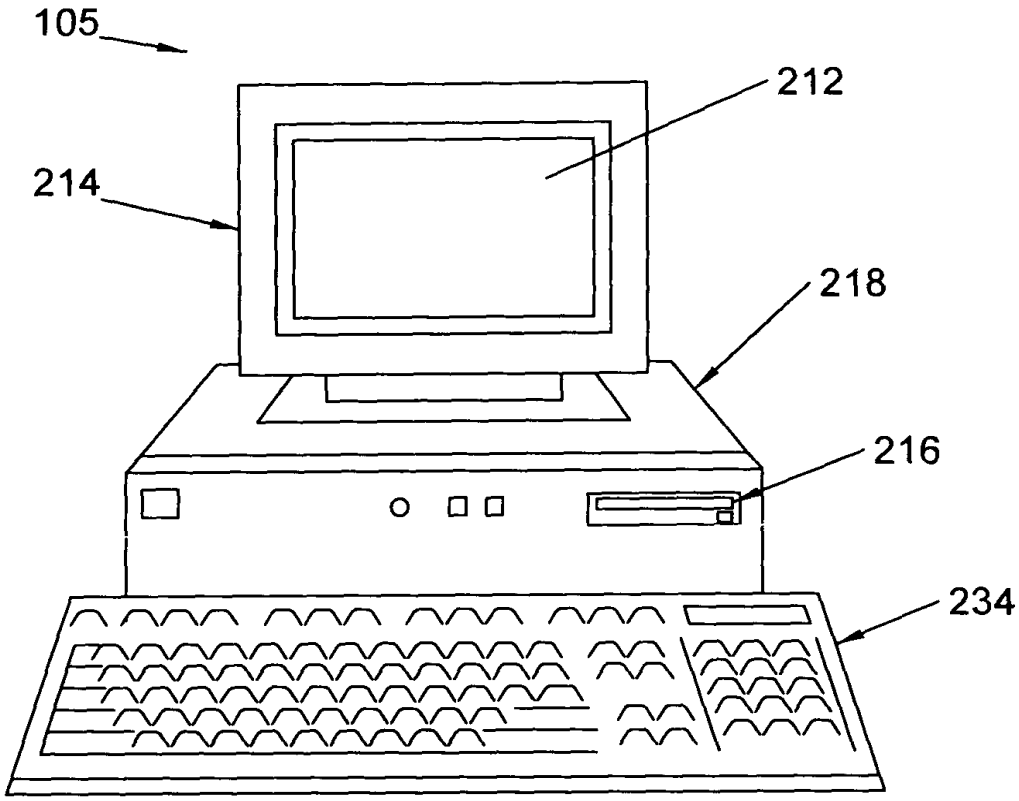
105
212
214
218
216
234

FIG. 2A

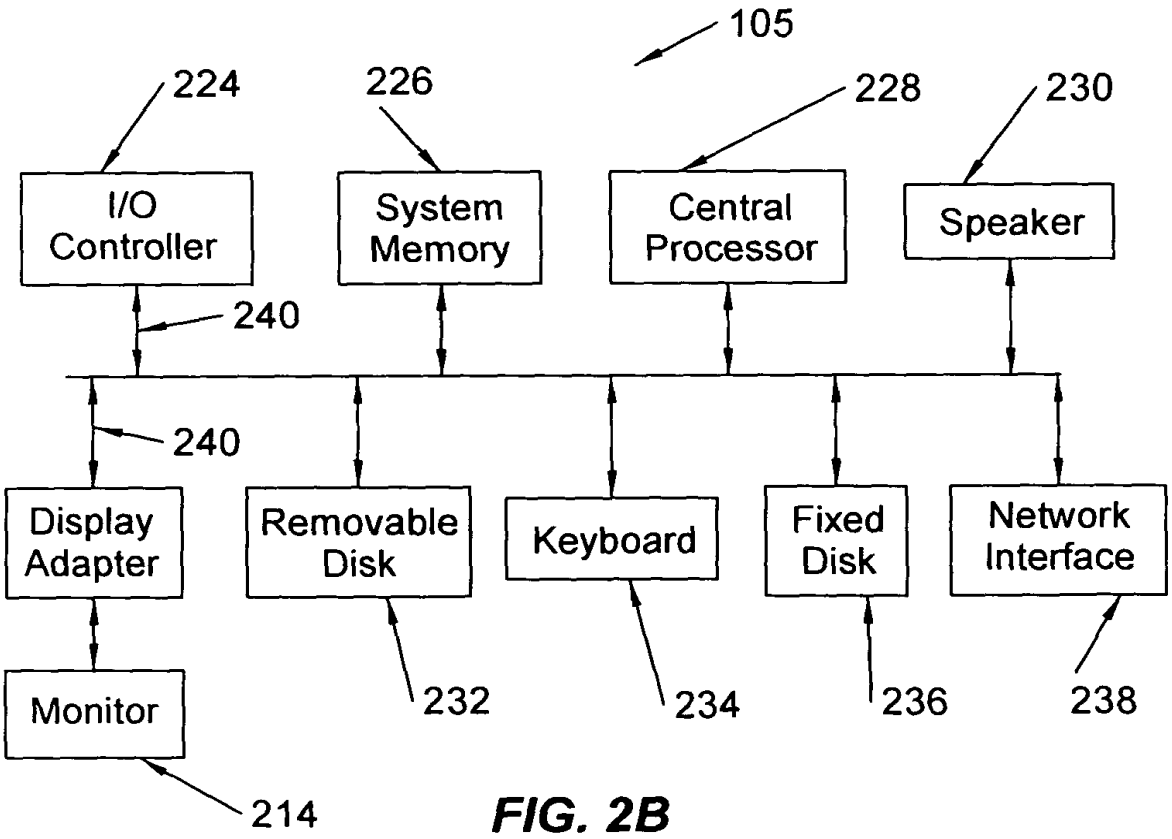
105
224
226
228
230
I/O Controller
System Memory
Central Processor
Speaker
240
240
Display Adapter
Removable Disk
Keyboard
Fixed Disk
Network Interface
Monitor
232
234
236
238
214

FIG. 2B

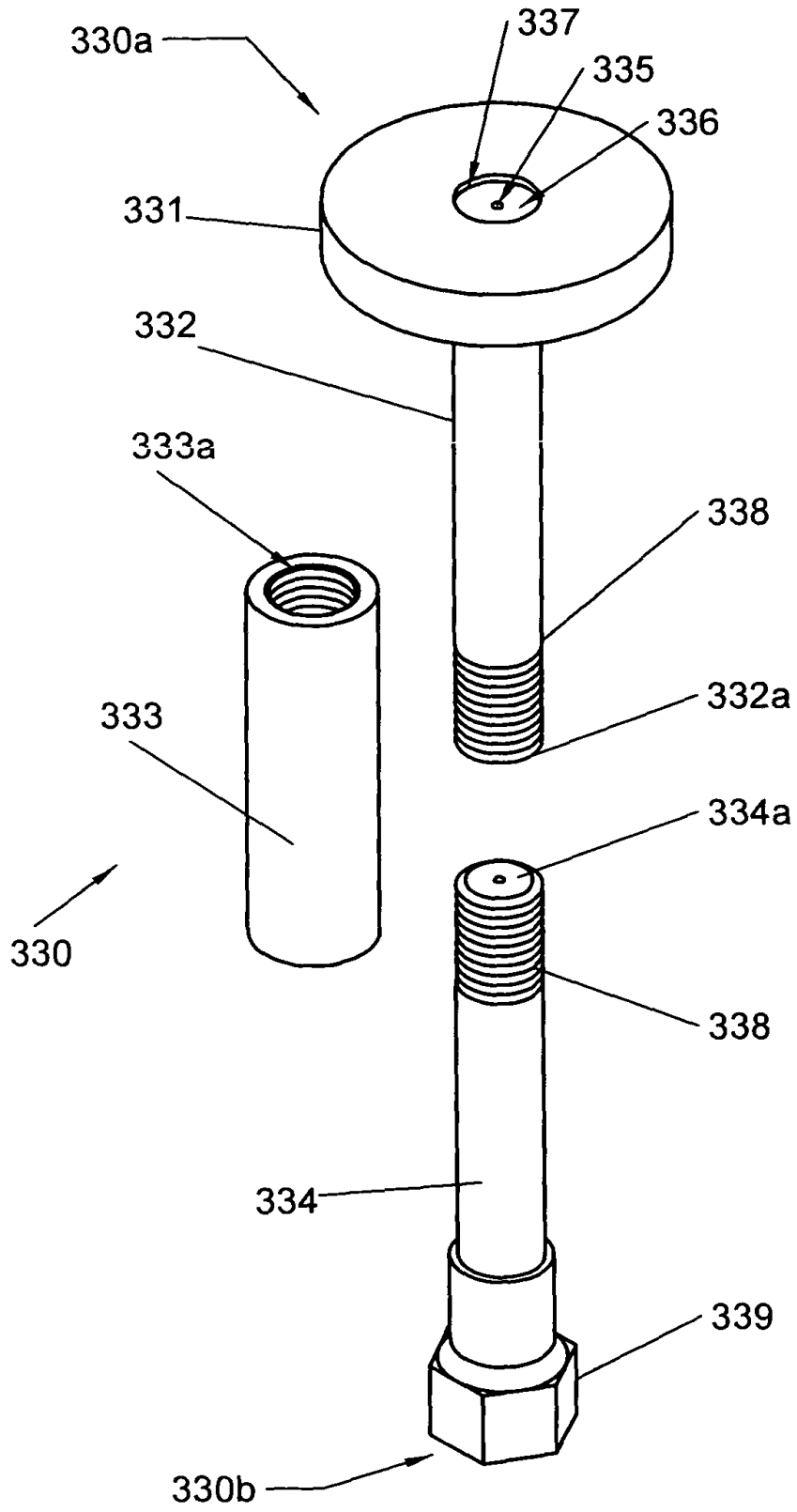
330a
337
335
336
331
332
333a
338
332a
333
334a
330
338
334
339
330b

FIG. 3A

20030228260T

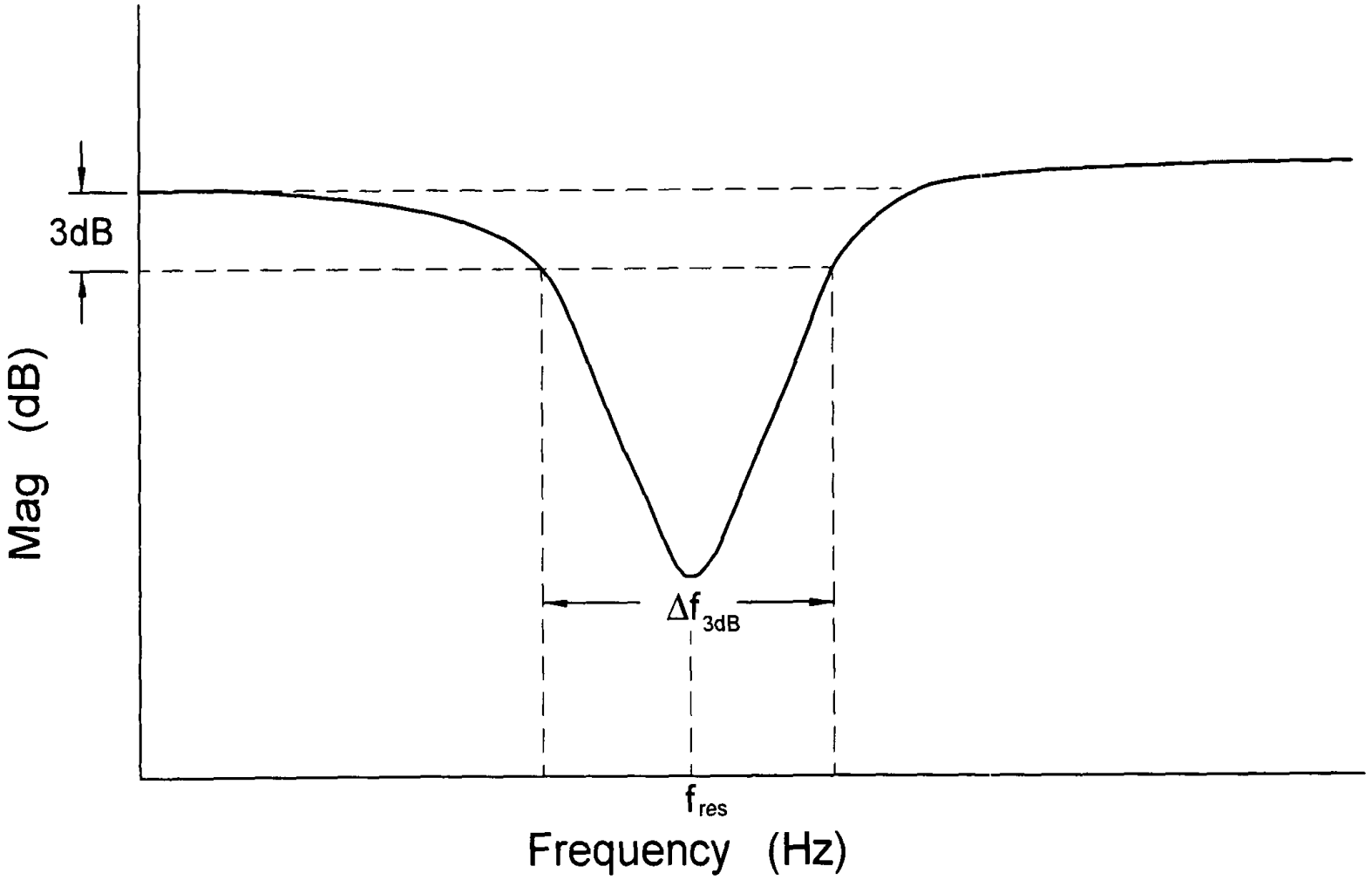

FIG. 3B

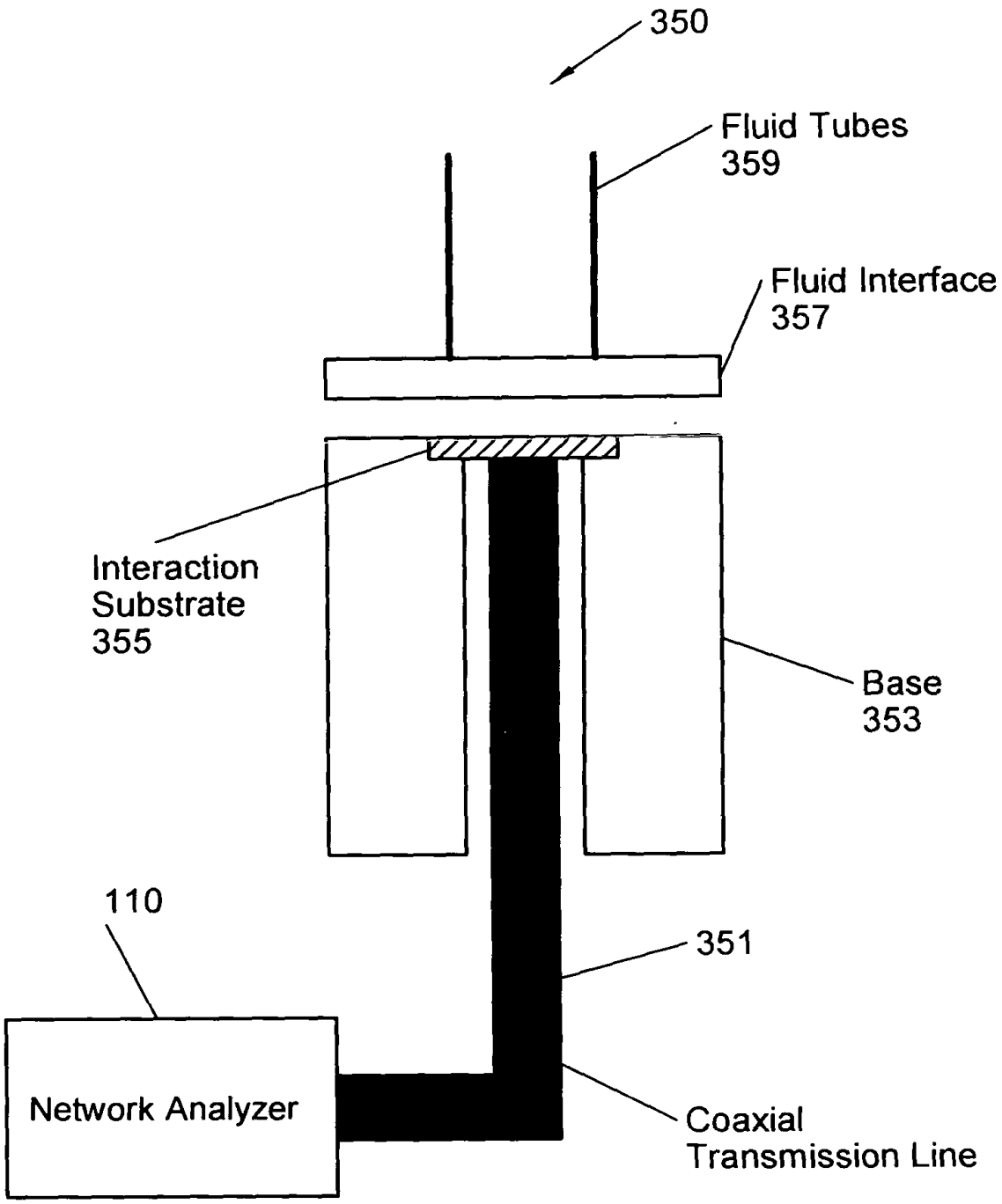
350
Fluid Tubes
359
Fluid Interface
357
Interaction
Substrate
355
Base
353
110
351
Network Analyzer
Coaxial
Transmission Line

FIG. 3C

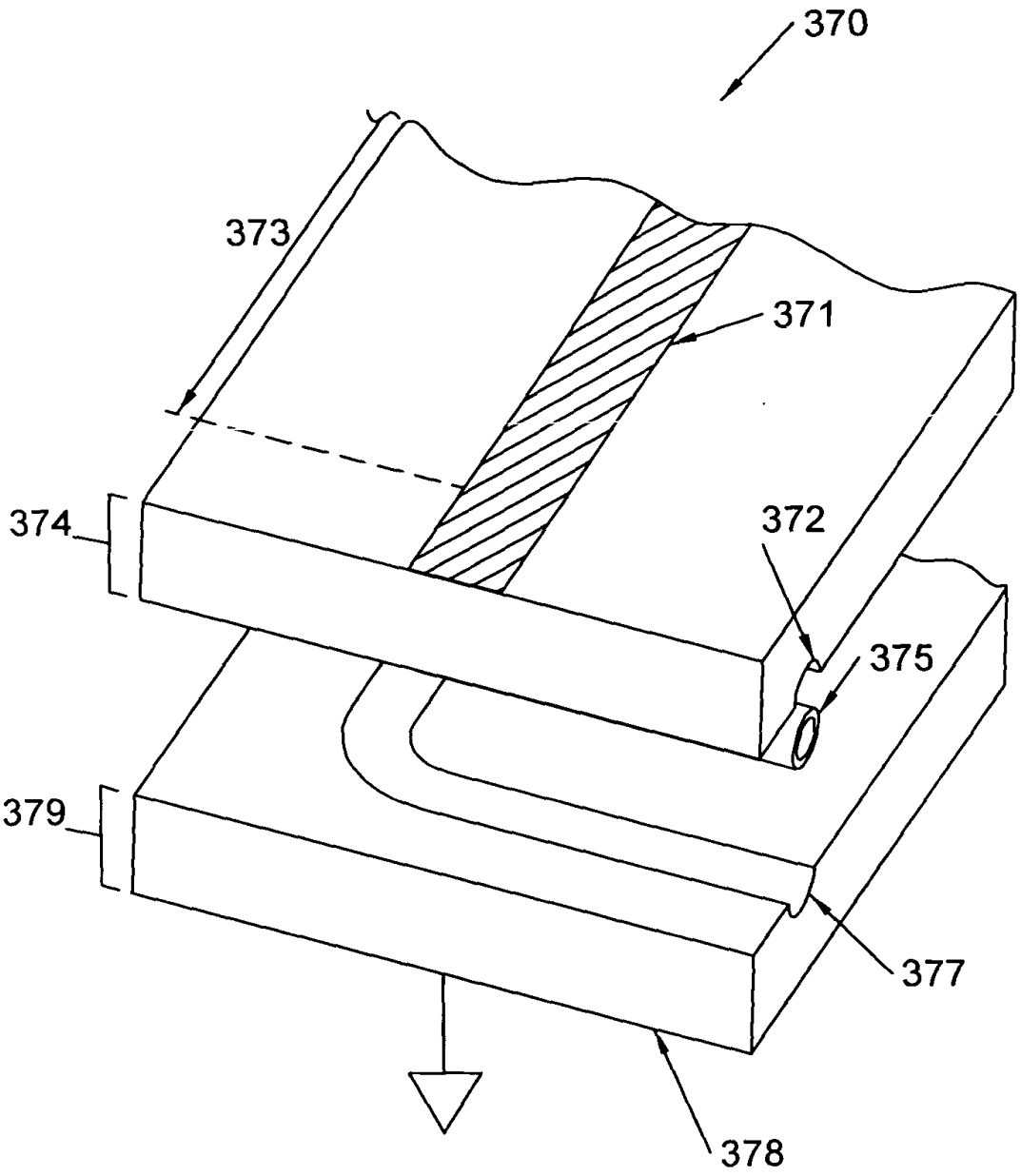

FIG. 3D

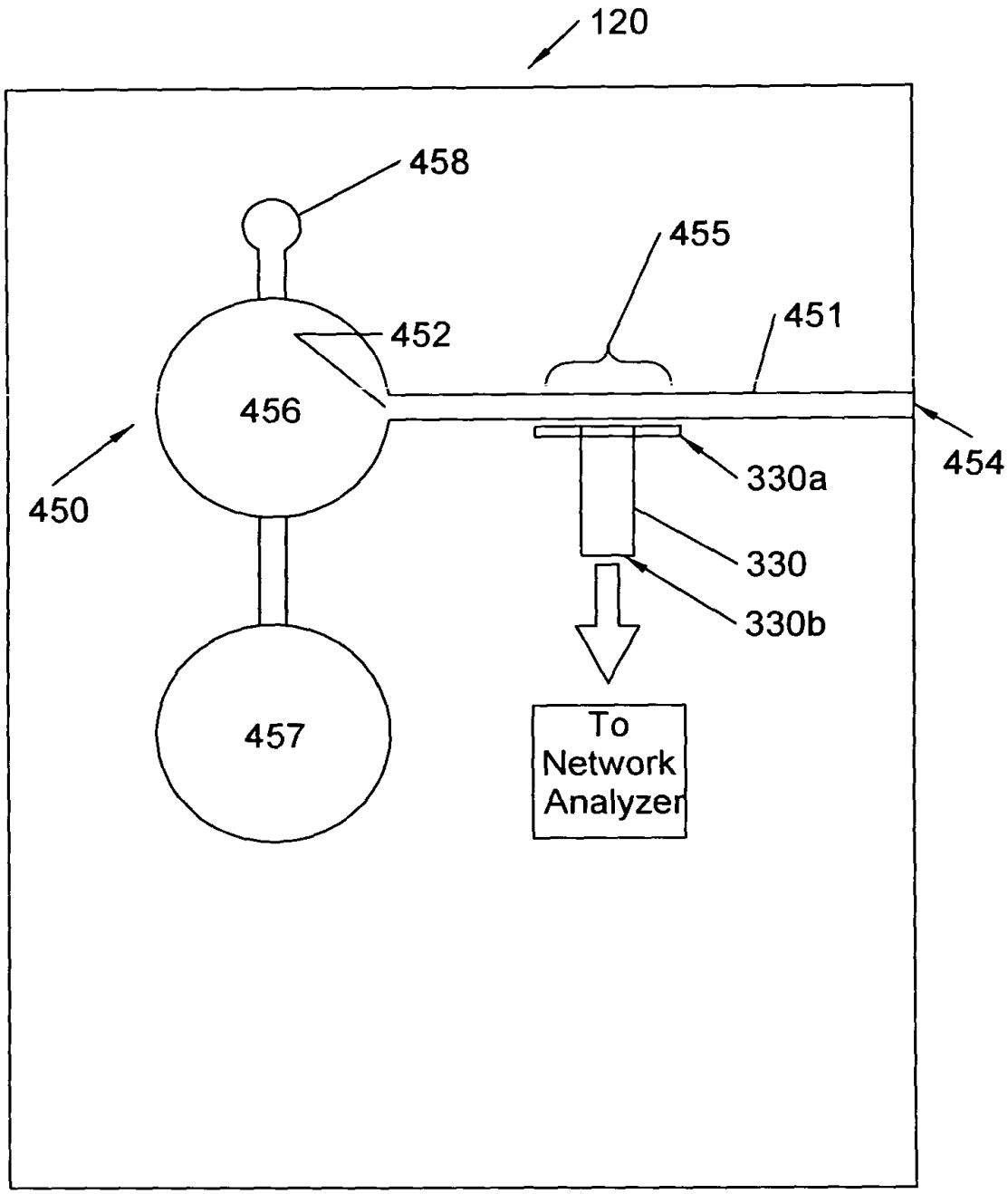
120
458
455
451
452
456
450
454
330a
330
330b
457
To
Network
Analyzer

FIG. 4A

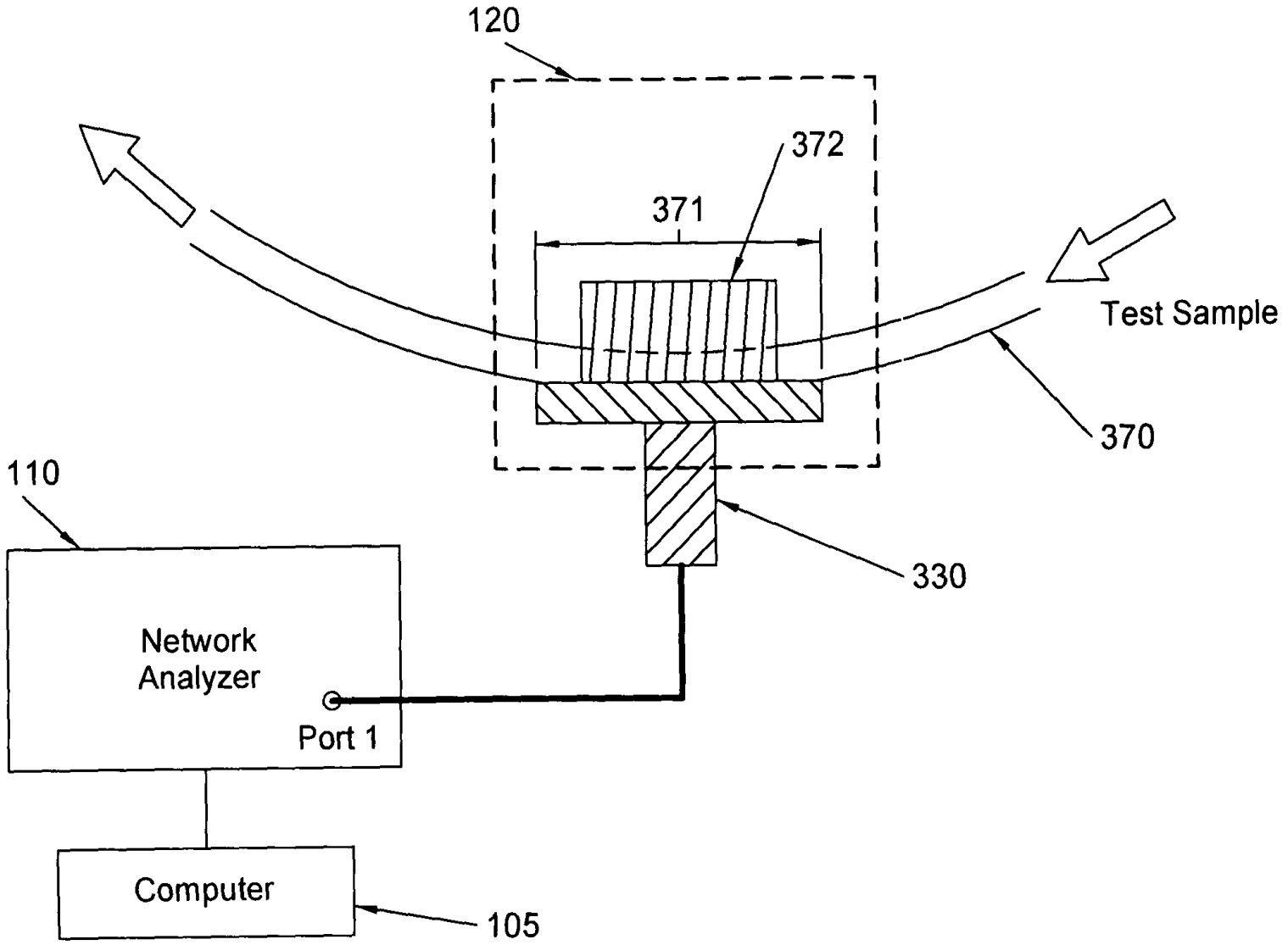
120
372
371
Test Sample
370
110
330
Network
Analyzer
Port 1
Computer
105

FIG. 4B

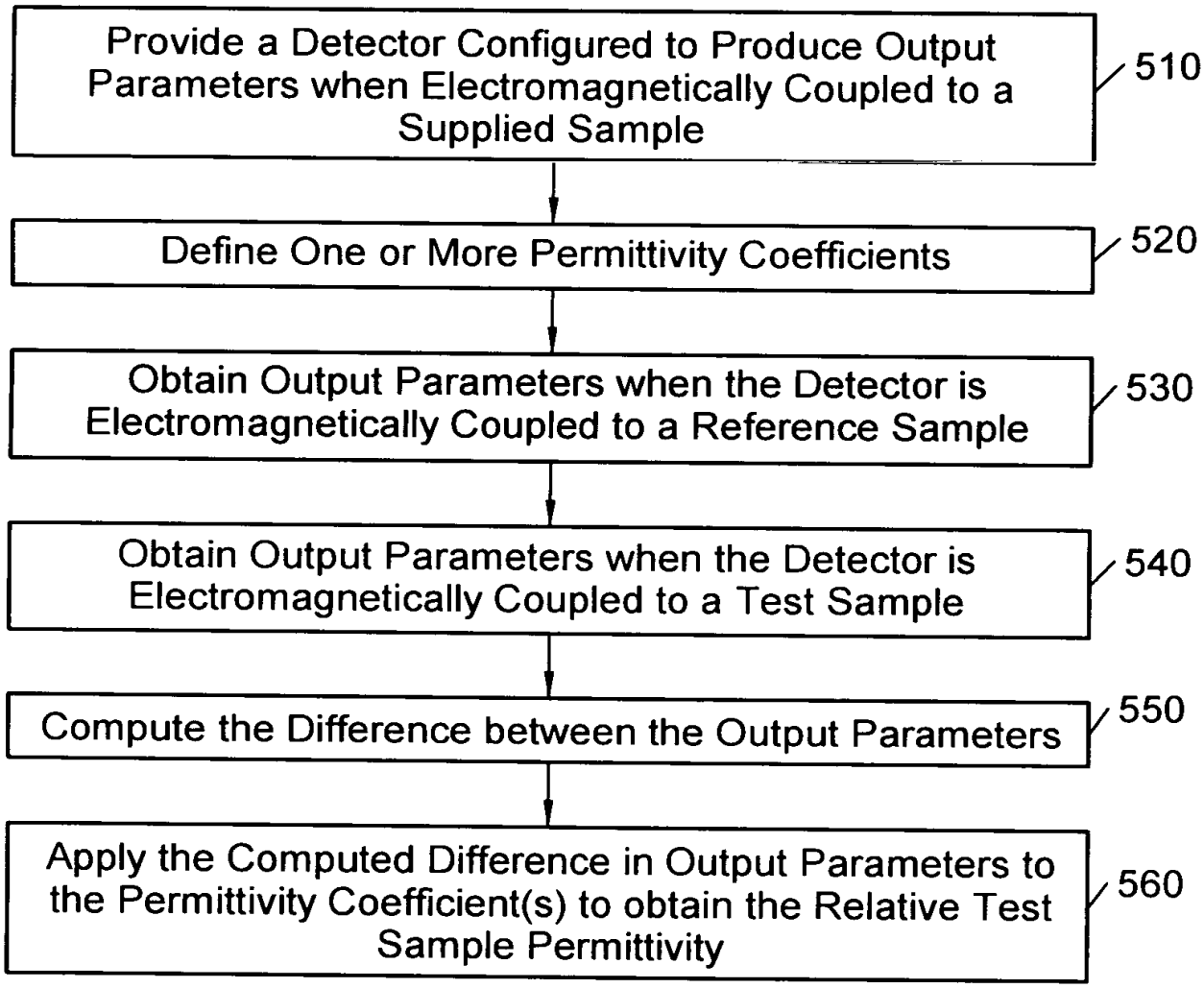
Provide a Detector Configured to Produce Output Parameters when Electromagnetically Coupled to a Supplied Sample
510
Define One or More Permittivity Coefficients
520
Obtain Output Parameters when the Detector is Electromagnetically Coupled to a Reference Sample
530
Obtain Output Parameters when the Detector is Electromagnetically Coupled to a Test Sample
540
Compute the Difference between the Output Parameters
550
Apply the Computed Difference in Output Parameters to the Permittivity Coefficient(s) to obtain the Relative Test Sample Permittivity
560

FIG. 5

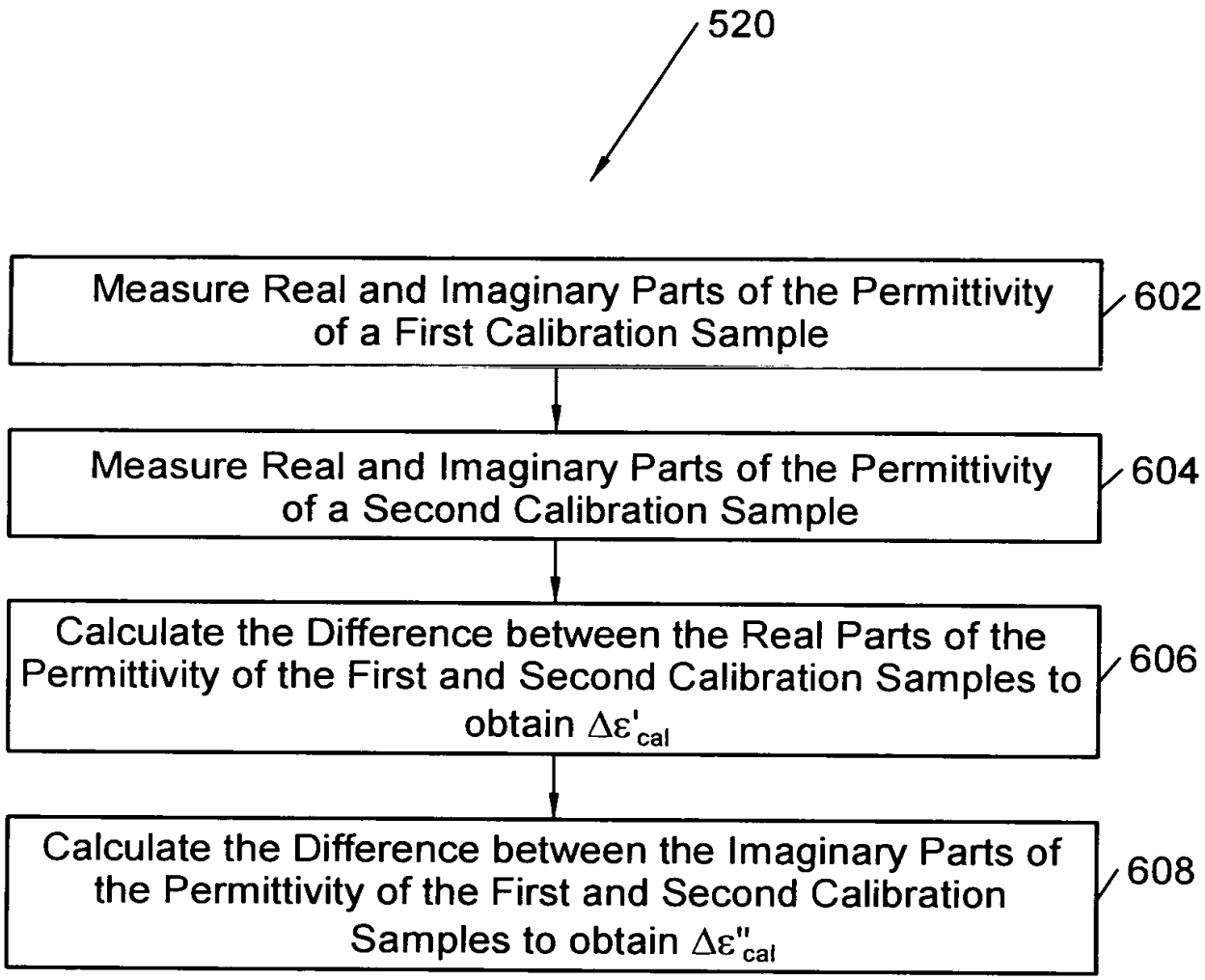
520
Measure Real and Imaginary Parts of the Permittivity of a First Calibration Sample
602
Measure Real and Imaginary Parts of the Permittivity of a Second Calibration Sample
604
Calculate the Difference between the Real Parts of the Permittivity of the First and Second Calibration Samples to obtain $\Delta\varepsilon'_{cal}$
606
Calculate the Difference between the Imaginary Parts of the Permittivity of the First and Second Calibration Samples to obtain $\Delta\varepsilon''_{cal}$
608

FIG. 6

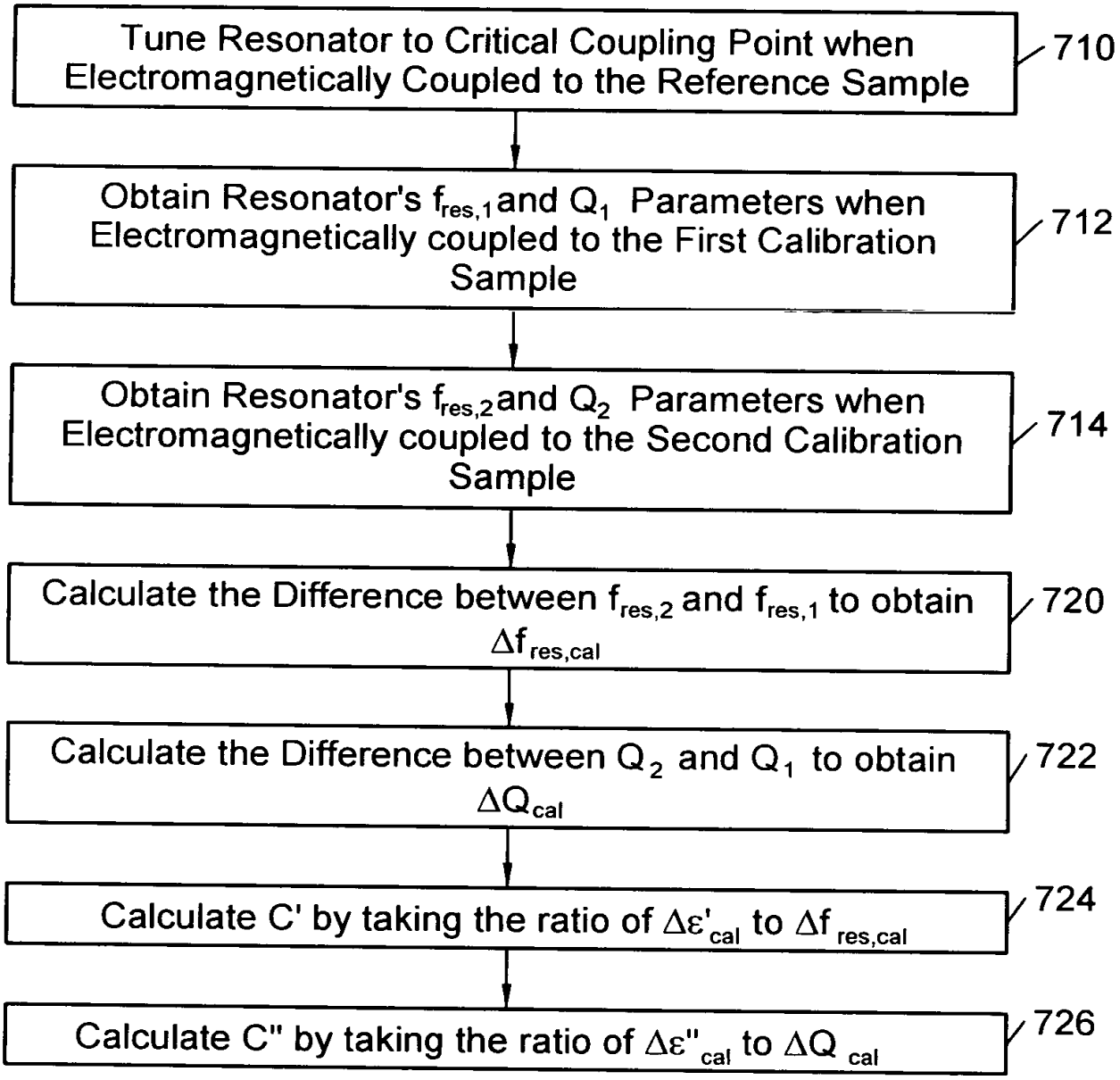
Tune Resonator to Critical Coupling Point when Electromagnetically Coupled to the Reference Sample
710
Obtain Resonator's $f_{res,1}$ and Q_1 Parameters when Electromagnetically coupled to the First Calibration Sample
712
Obtain Resonator's $f_{res,2}$ and Q_2 Parameters when Electromagnetically coupled to the Second Calibration Sample
714
Calculate the Difference between $f_{res,2}$ and $f_{res,1}$ to obtain $\Delta f_{res,cal}$
720
Calculate the Difference between Q_2 and Q_1 to obtain ΔQ_{cal}
722
Calculate C' by taking the ratio of $\Delta\varepsilon'_{cal}$ to $\Delta f_{res,cal}$
724
Calculate C" by taking the ratio of $\Delta\varepsilon''_{cal}$ to ΔQ_{cal}
726

FIG. 7A

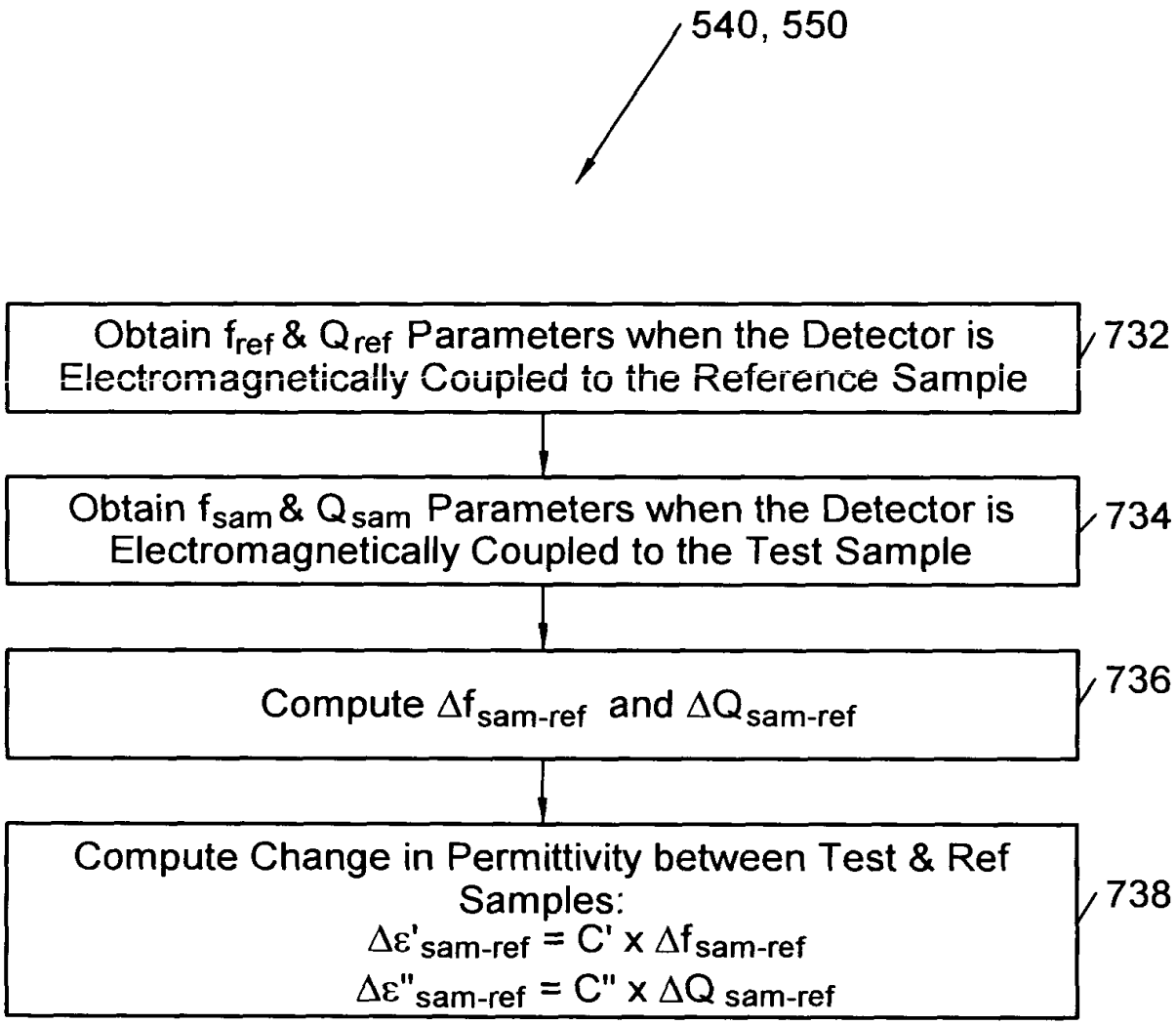
540, 550
Obtain f_{ref} & Q_{ref} Parameters when the Detector is Electromagnetically Coupled to the Reference Sample
732
Obtain f_{sam} & Q_{sam} Parameters when the Detector is Electromagnetically Coupled to the Test Sample
734
Compute $\Delta f_{sam-ref}$ and $\Delta Q_{sam-ref}$
736
Compute Change in Permittivity between Test & Ref Samples:
$\Delta\varepsilon'_{sam-ref} = C' \times \Delta f_{sam-ref}$
$\Delta\varepsilon''_{sam-ref} = C'' \times \Delta Q_{sam-ref}$
738

FIG. 7B

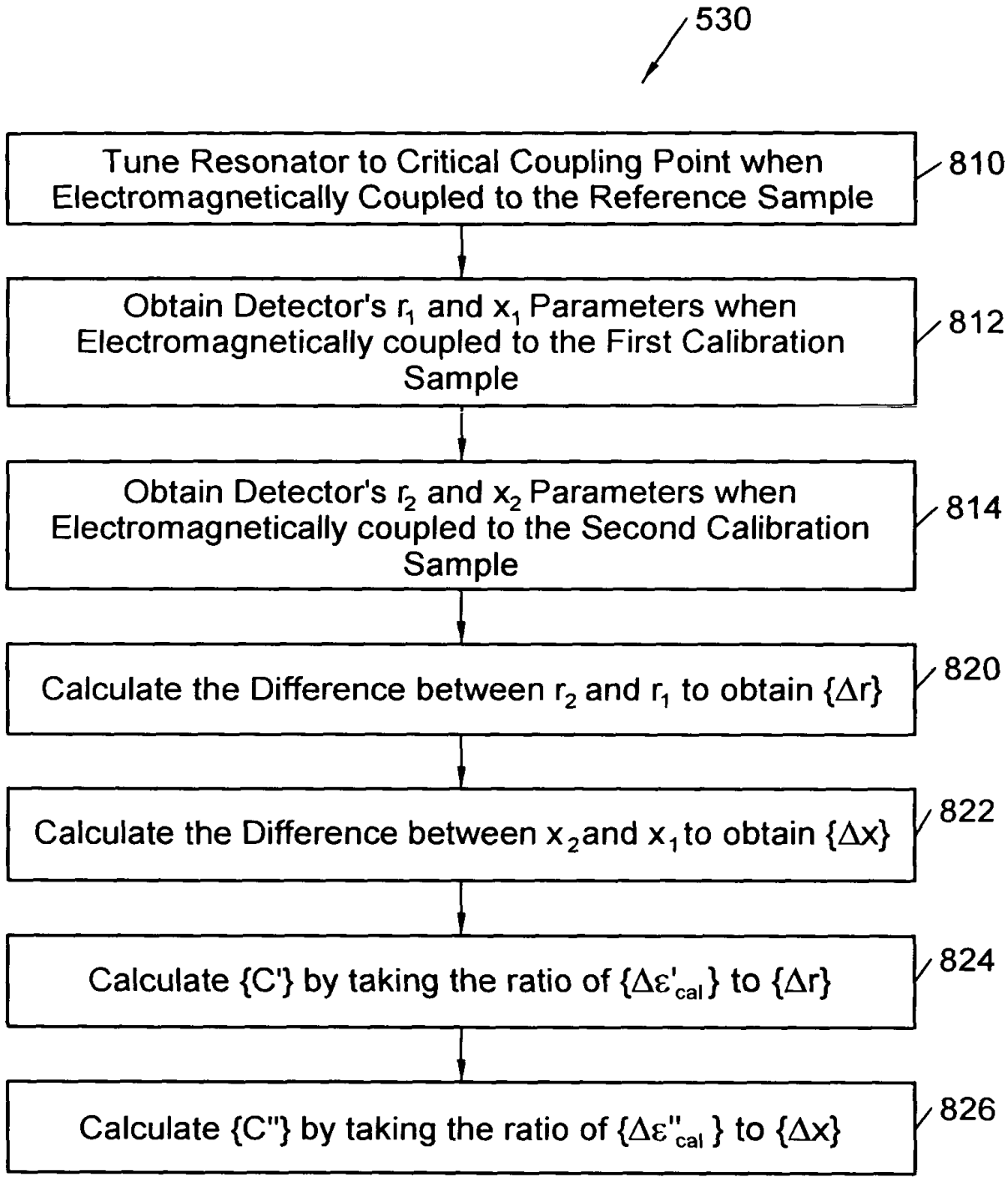
530
Tune Resonator to Critical Coupling Point when Electromagnetically Coupled to the Reference Sample
810
Obtain Detector's r_1 and x_1 Parameters when Electromagnetically coupled to the First Calibration Sample
812
Obtain Detector's r_2 and x_2 Parameters when Electromagnetically coupled to the Second Calibration Sample
814
Calculate the Difference between r_2 and r_1 to obtain $\{\Delta r\}$
820
Calculate the Difference between x_2 and x_1 to obtain $\{\Delta x\}$
822
Calculate $\{C'\}$ by taking the ratio of $\{\Delta\varepsilon'_{cal}\}$ to $\{\Delta r\}$
824
Calculate $\{C''\}$ by taking the ratio of $\{\Delta\varepsilon''_{cal}\}$ to $\{\Delta x\}$
826

FIG. 8A

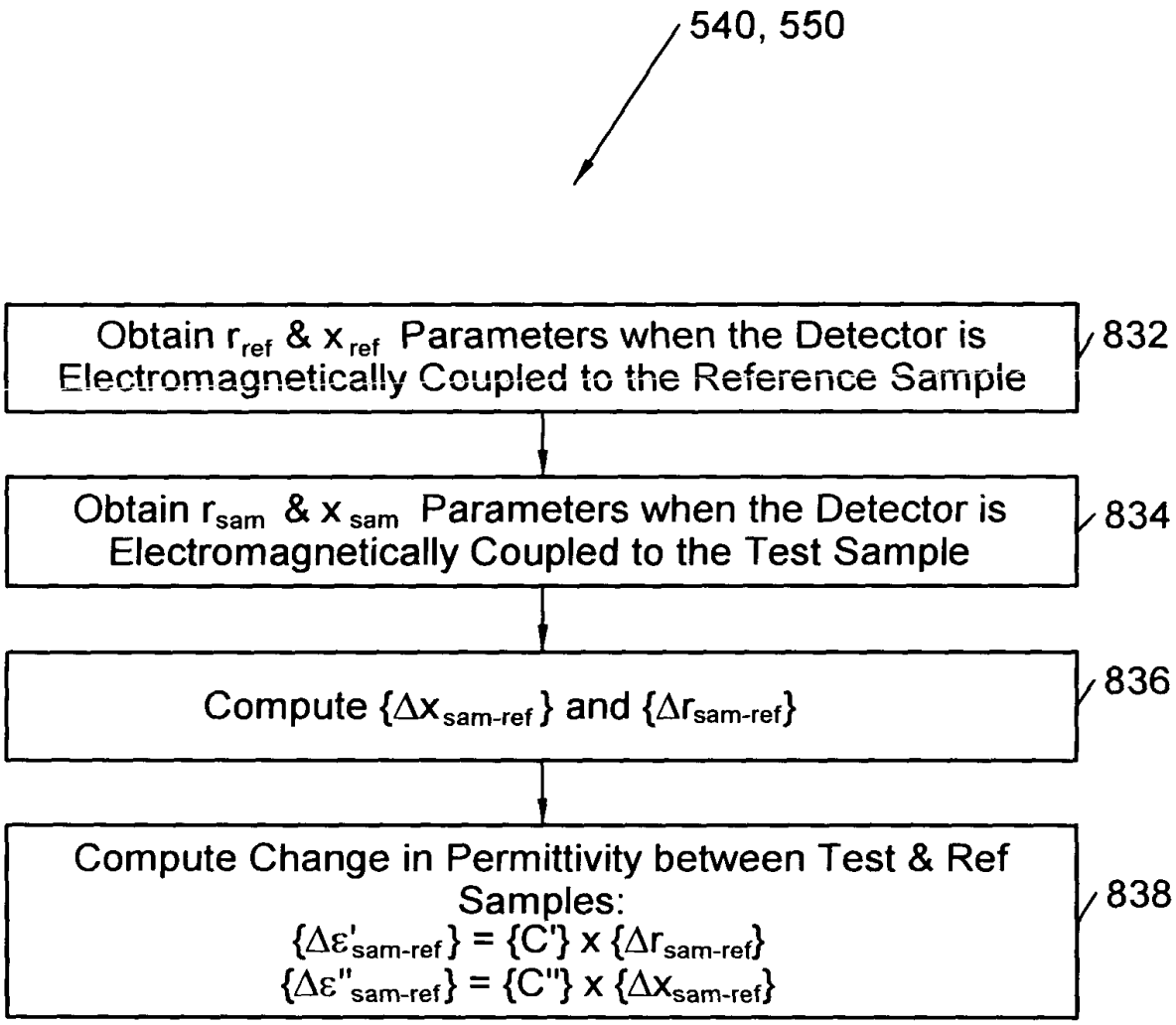
540, 550
Obtain r_{ref} & x_{ref} Parameters when the Detector is Electromagnetically Coupled to the Reference Sample
832
Obtain r_{sam} & x_{sam} Parameters when the Detector is Electromagnetically Coupled to the Test Sample
834
Compute $\{\Delta x_{sam-ref}\}$ and $\{\Delta r_{sam-ref}\}$
836
Compute Change in Permittivity between Test & Ref Samples:
$\{\Delta\varepsilon'_{sam-ref}\} = \{C'\} \times \{\Delta r_{sam-ref}\}$
$\{\Delta\varepsilon''_{sam-ref}\} = \{C''\} \times \{\Delta x_{sam-ref}\}$
838

FIG. 8B

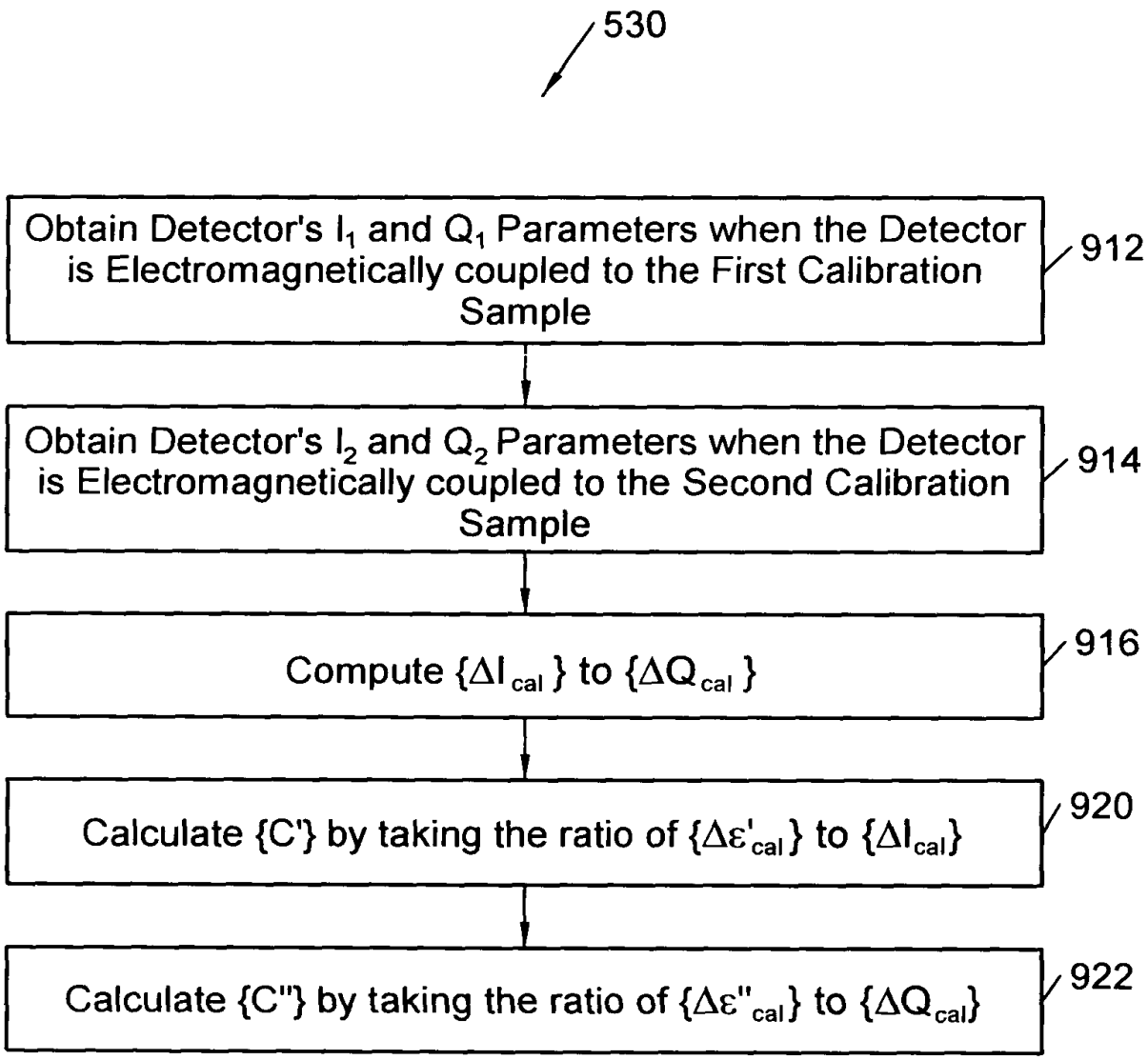
530
Obtain Detector's I_1 and Q_1 Parameters when the Detector is Electromagnetically coupled to the First Calibration Sample
912
Obtain Detector's I_2 and Q_2 Parameters when the Detector is Electromagnetically coupled to the Second Calibration Sample
914
Compute $\{\Delta I_{cal}\}$ to $\{\Delta Q_{cal}\}$
916
Calculate $\{C'\}$ by taking the ratio of $\{\Delta\varepsilon'_{cal}\}$ to $\{\Delta I_{cal}\}$
920
Calculate $\{C''\}$ by taking the ratio of $\{\Delta\varepsilon''_{cal}\}$ to $\{\Delta Q_{cal}\}$
922

FIG. 9A

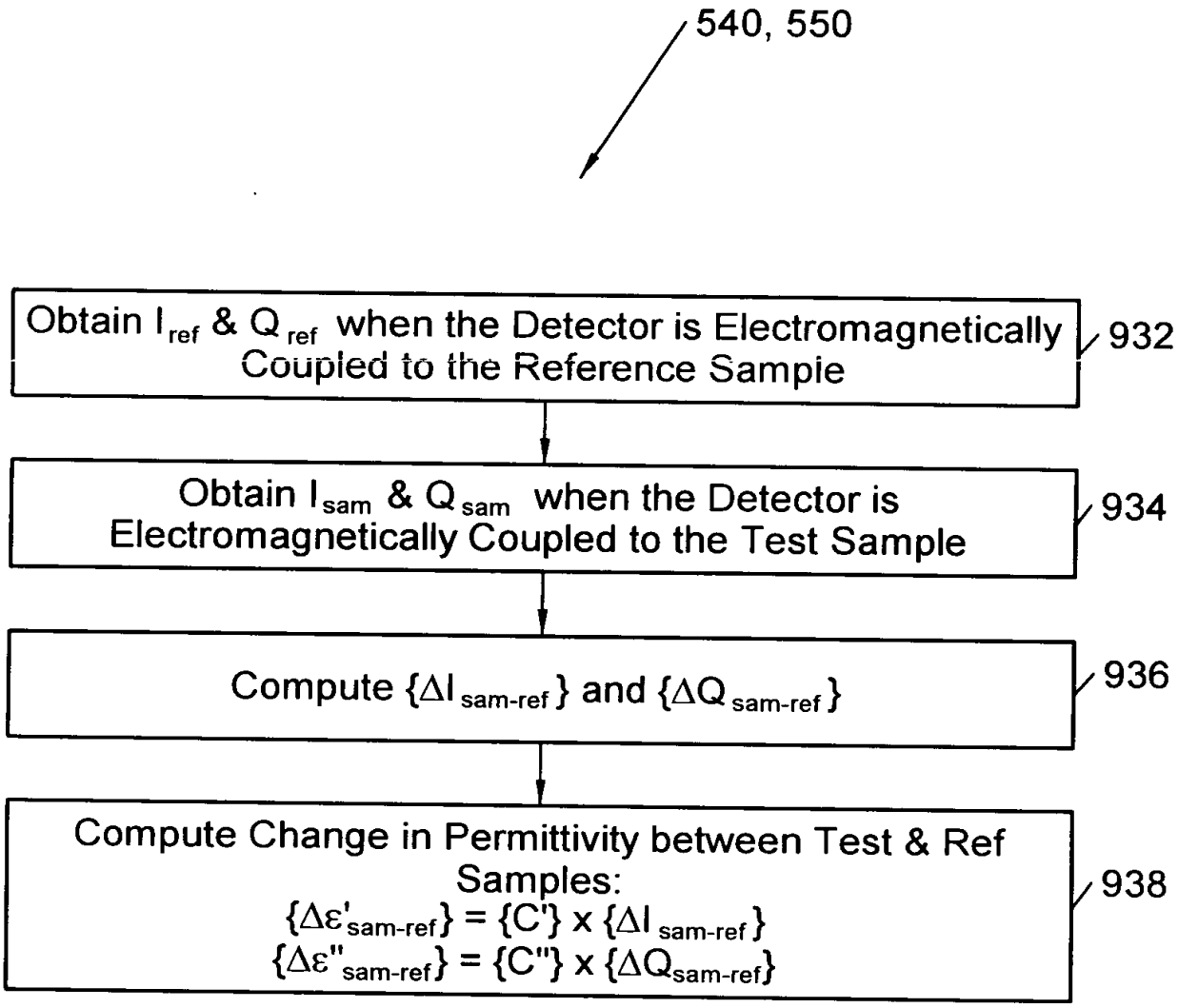
540, 550
Obtain I_{ref} & Q_{ref} when the Detector is Electromagnetically Coupled to the Reference Sample
932
Obtain I_{sam} & Q_{sam} when the Detector is Electromagnetically Coupled to the Test Sample
934
Compute $\{\Delta I_{sam-ref}\}$ and $\{\Delta Q_{sam-ref}\}$
936
Compute Change in Permittivity between Test & Ref Samples:
$\{\Delta\varepsilon'_{sam-ref}\} = \{C'\} \times \{\Delta I_{sam-ref}\}$
$\{\Delta\varepsilon''_{sam-ref}\} = \{C''\} \times \{\Delta Q_{sam-ref}\}$
938

FIG. 9B

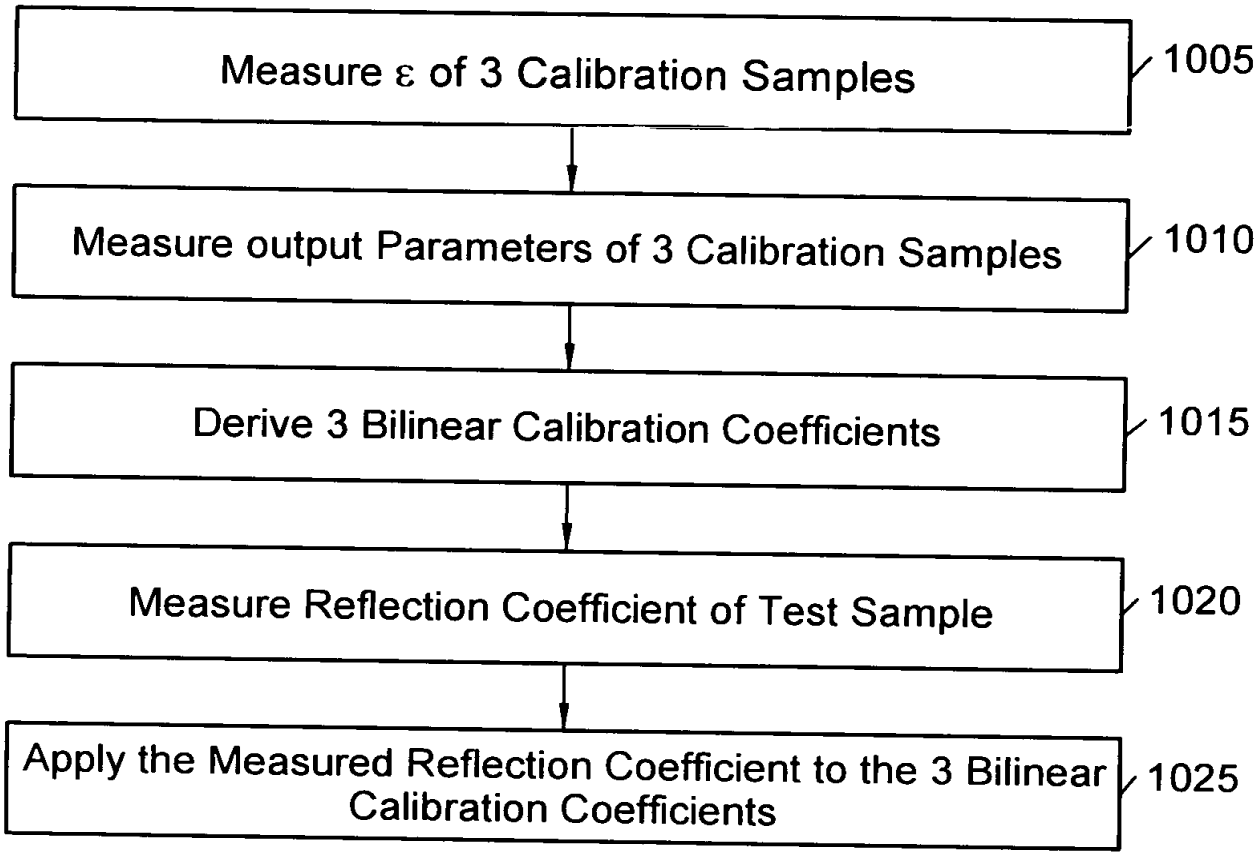
Measure ε of 3 Calibration Samples
1005
Measure output Parameters of 3 Calibration Samples
1010
Derive 3 Bilinear Calibration Coefficients
1015
Measure Reflection Coefficient of Test Sample
1020
Apply the Measured Reflection Coefficient to the 3 Bilinear Calibration Coefficients
1025

FIG. 10

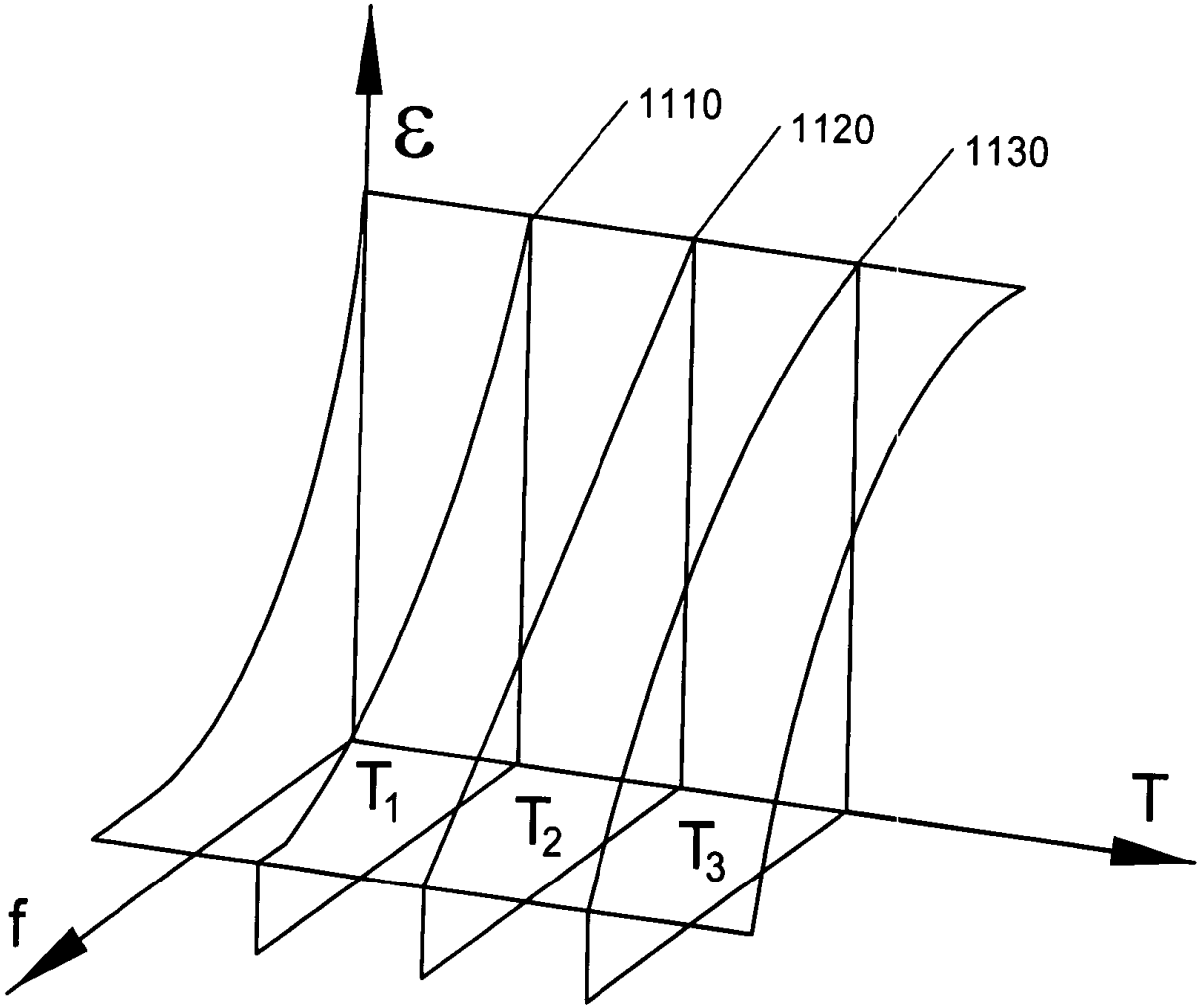

FIG. 11

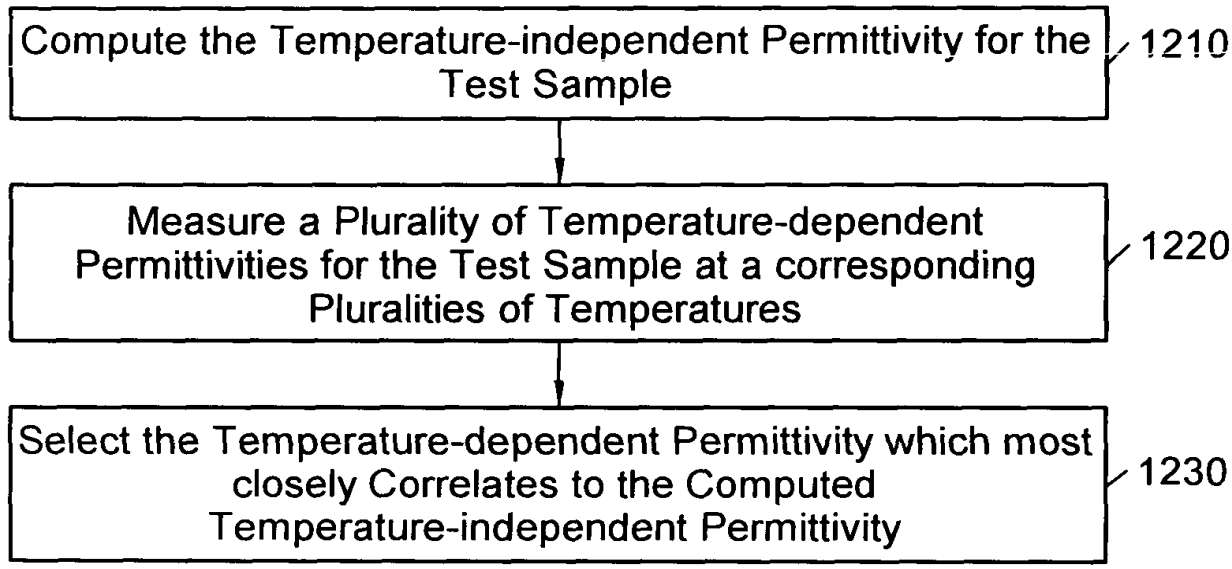
Compute the Temperature-independent Permittivity for the Test Sample
1210
Measure a Plurality of Temperature-dependent Permittivities for the Test Sample at a corresponding Pluralities of Temperatures
1220
Select the Temperature-dependent Permittivity which most closely Correlates to the Computed Temperature-independent Permittivity
1230

FIG. 12A

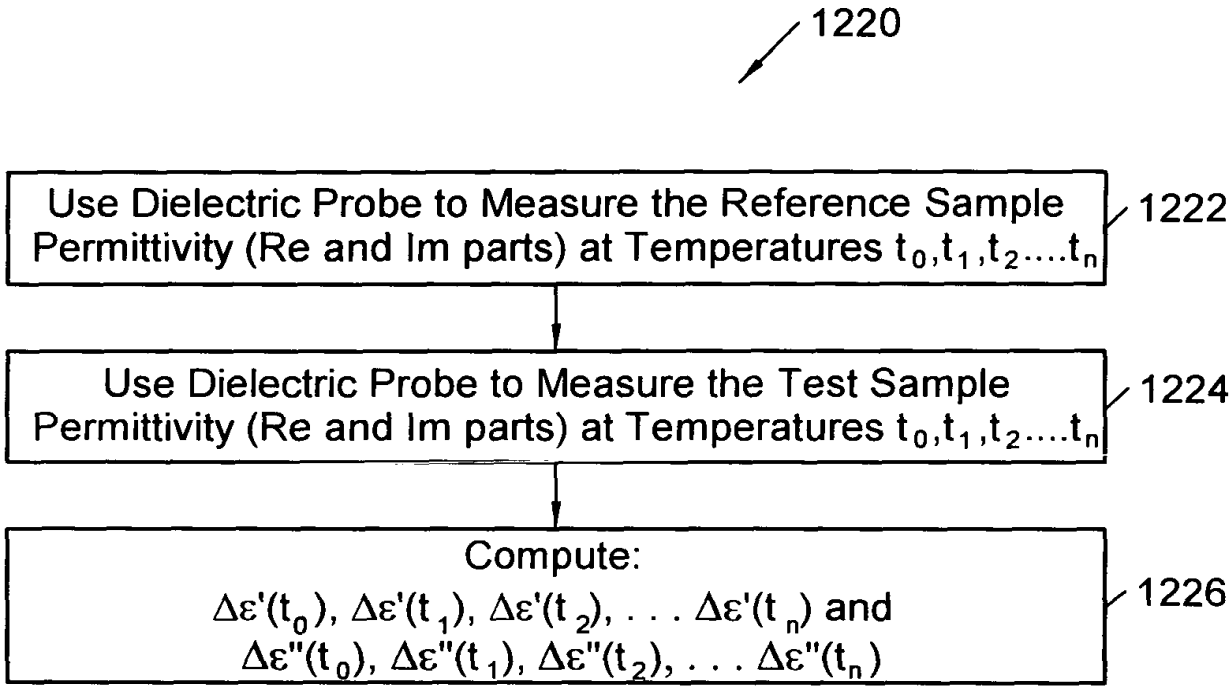

FIG. 12B

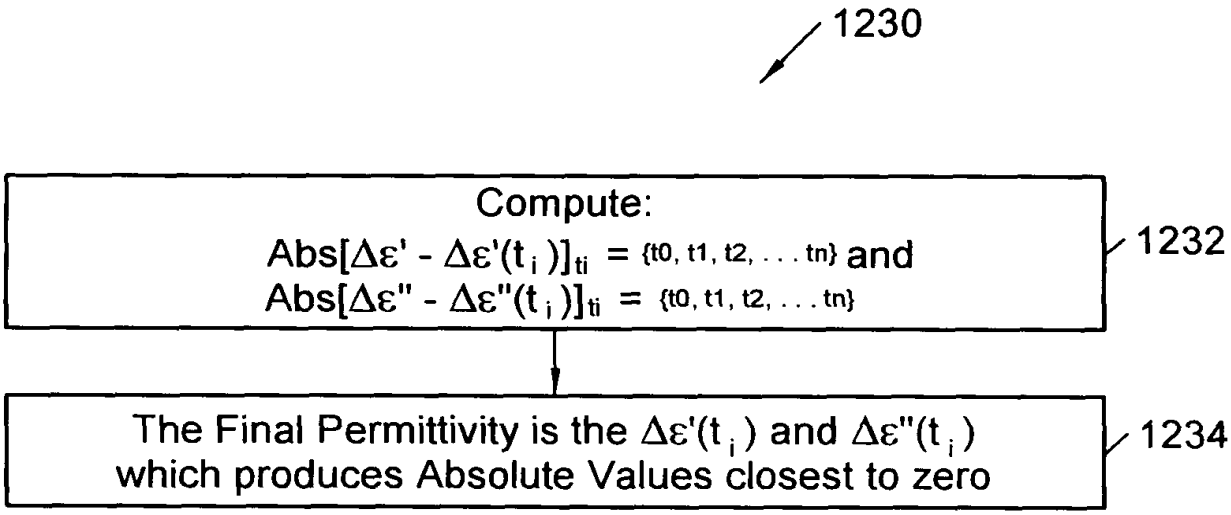

FIG. 12C